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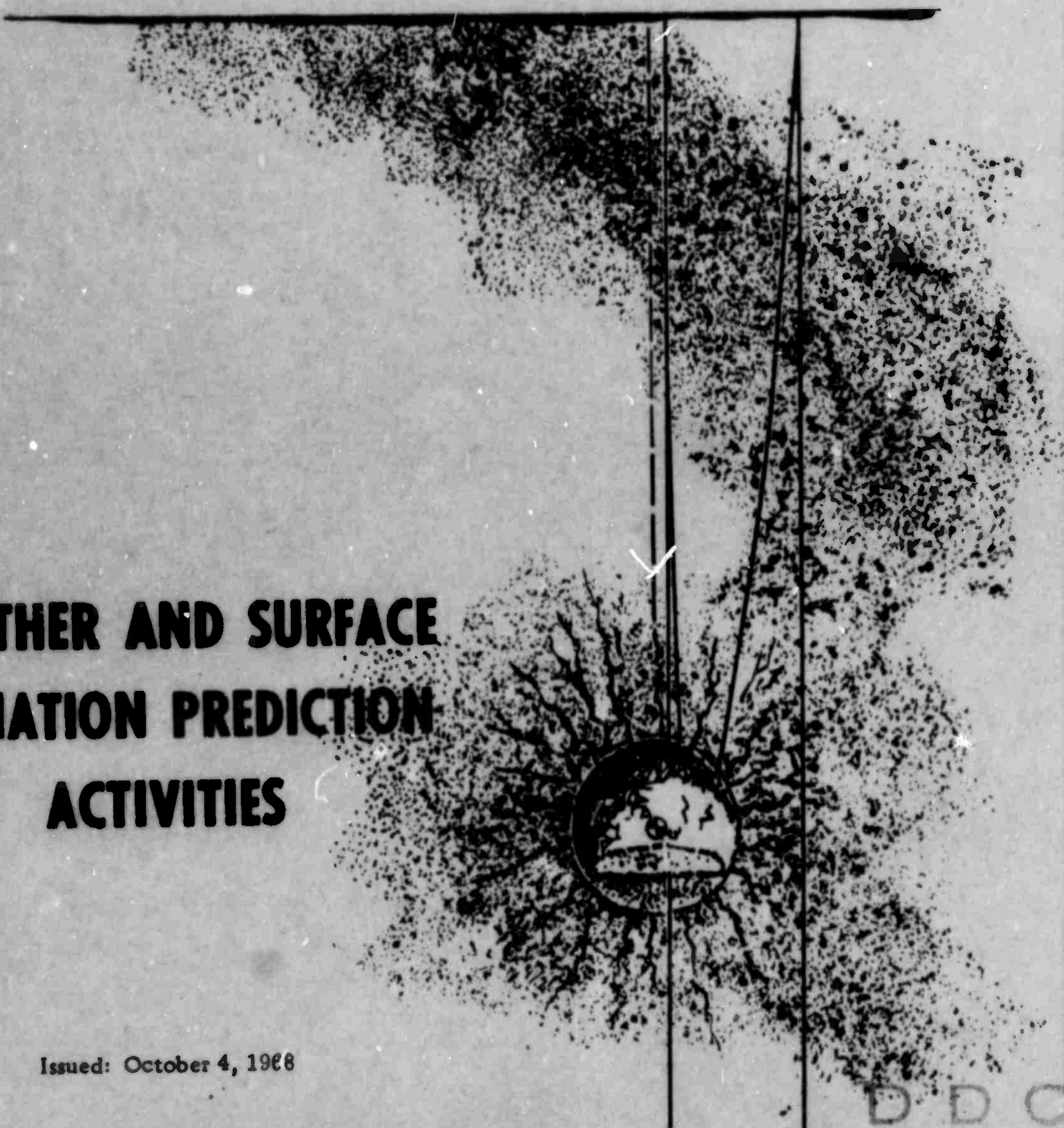
VELA UNIFORM PROGRAM

STERLING EVENT



WEATHER AND SURFACE RADIATION PREDICTION ACTIVITIES

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Reynolds Electrical and Engineering Co., Inc.
Mercury, Nevada

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U. S. Department of Commerce

Environmental Science Services Administration

Environmental Research Laboratories

FINAL REPORT

of

WEATHER and SURFACE RADIATION PREDICTION ACTIVITIES

for the

STERLING EVENT - PROJECT STERLING

by

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CONTENTS

Abstract

In support of the Project Sterling Technical and Safety Programs, the Air Resources Laboratory - Las Vegas, Las Vegas, Nevada, provided meteorological services which included the compilation of climatological summaries, a program of surface and upper-air meteorological observations, and the preparation of weather and radiation predictions. These services are described and weather and radiation chronologies, relevant to shot-day, are recounted.

CHAPTER I

INTRODUCTION

1.1 OBJECTIVES

The Sterling Event was a planned 350-ton nuclear explosion detonated in the cavity created by Project Salmon in the Tatum Salt Dome about 20 miles southwest of Hattiesburg, Mississippi.

The objectives of Project Sterling were:

1. To determine the extent of decoupling of a sprung cavity (the cavity produced by the Salmon Event) in a salt medium.
2. To determine the accuracy of decoupling calculations for a sprung cavity.
3. To define any operational problems associated with the re-use of a cavity created by a nuclear detonation.

The Sterling Event was conducted at 0615 CST, December 3, 1966. Ground Zero was located at geodetic coordinates N 31° 8' 29", W 89° 34' 33". No significant amount of radioactivity produced by the detonation was released into the atmosphere. Although containment of all radioactivity was expected with a high degree of confidence, certain pre-shot safety measures were implemented, nevertheless, to insure that any leakage of radioactivity would not constitute a hazard to the population or livestock in the vicinity of the site.

The technical program and safety measures stated above established a requirement for certain weather conditions in order to conduct the experiment. These weather conditions were as follows:

1. Surface wind speeds of less than approximately 20 mph.

2. Cloud ceiling and visibility sufficient to permit aircraft operations at and below the predicted upper limit of vertical mixing.

3. No precipitation

The primary objectives of the Air Resources Laboratory - Las Vegas (ARL-LV), Las Vegas, Nevada, were to provide meteorological data and weather forecasting services in support of the Test Director's Program and the Operational Safety Plan and to provide predictions of the dispersion of any radioactive effluent which may have been released as a result of the Sterling Event. Additional objectives of the ARL-LV were to measure, analyze, and disseminate meteorological data and information to participants in the Sterling program prior to and during the event and to provide post-shot analyses, records, and reports consistent with the experiment.

1.2 FUNCTIONS

Forecasts of meteorological elements pertinent to test activities and estimates of the total external gamma dose produced by the passage of the potential effluent cloud were made available to the Project Manager and his Advisory Panel, in both formal and informal briefings, prior to the detonation. The Weather and Radiation Prediction Unit (WRPU) was responsible for the collection and interpretation of meteorological data and for advising test personnel on matters influenced by the state of the atmosphere. The unit worked in close cooperation with these individuals to insure that the Safety Program had the benefit of the most accurate,

current, and useful information possible.

1.3 ORGANIZATION

The WRPU functioned under the direction of the Director, Effects Safety Division, with operational control of the unit exercised by the Project Manager during the execution period of the Sterling Event. The Chief, ARL-LV, Las Vegas, Nevada, was in charge of the unit, which was composed entirely of technical personnel provided by that office.

From scheduled D-7 days to the actual time of the event, the unit consisted of six meteorological technicians, who conducted surface, radiosonde, and winds-aloft observations and processed meteorological data; one electronics technician, who maintained meteorological equipment; and three meteorologists, who provided forecasts of meteorological parameters and prepared radiation estimates.

CHAPTER II

PROCEDURE

2.1 OBSERVATIONAL PROCEDURES

The installation of meteorological equipment at the Project Sterling site was initiated during October 1966. Instrument locations were selected so as to provide data which would best satisfy the requirements set forth in the Operational Safety Plan.

An M-33 radar upper-wind station and a meteorological observations trailer were emplaced in the CP area, about one mile east-northeast of Ground Zero. A low-level wind direction and speed sensor was installed atop a 57-foot tower erected about 240 feet southwest of Ground Zero, with data telemetered to analog recorders in the Technical Director's Trailer and the Weather Operations Trailer in the CP area. A second low-level wind direction and speed sensor was installed at the top of a 40-foot tower in the CP area, with data telemetered to analog recorders in the Weather Operations Trailer only. Pibal upper-wind stations were established off-site at the Columbia, Hattiesburg, and Lumberton airports, 18 miles northwest, 21 miles northeast, and 12 miles southeast of Ground Zero, respectively.

Hard-wire telemetry was used to transmit data from the low-level wind instrumentation to the Technical Director's Trailer and the Weather Operations Trailer. Radio and telephone communications were utilized to transmit data from the off-site winds-aloft stations. Facsimile and teletype receivers were installed in the Weather Operations Trailer for reception of regional and national meteorological information.

The original readiness date for the Sterling experiment was 0600 CST, November 29, 1966. Commencing 10 days prior to this date, D-10, the following meteorological observations were conducted daily on a routine basis at the CP:

1. Upper winds at 3-hour intervals from 0000 CST to 1500 CST.
2. Hourly surface weather observations on a 24-hour-per-day basis.

Commencing on D-5, upper-air pressure, temperature, and humidity observations were conducted at 0000 CST and 0600 CST.

On the day of the event, D-day, the schedule of observations was as follows:

1. Upper winds from the CP area at hourly intervals, beginning at 0000 CST. The frequency of these observations was increased to half-hourly as the scheduled H-hour, 0615 CST, approached.
2. Upper winds from both Hattiesburg and Columbia airports at hourly intervals, beginning at 0100 CST.
3. Upper-air observations of pressure, temperature, and humidity in the CP area as required, commencing at 0100 CST.
4. Low-level wind observations from the two on-site tower locations as required.
5. Hourly surface weather observations supplemented by additional observations as necessary.

2.2 ANALYSIS PROCEDURES

2.2.1 Climatological Analysis Procedures

Climatological statistics applicable to the Sterling Event

were compiled as described in the publication, "Final Report of Weather and Surface Radiation Prediction Activities for the Salmon Event-- Project Dribble", by the Staff, Weather Bureau Research Station, Las Vegas, Nevada, issued December 14, 1965. Climatological data cited in the above document were supplemented by those data obtained on-site during the operational phase of the Salmon Event.

At the request of the Project Manager, special frequency summaries, by hour, of surface wind speed, cloud cover, rain, fog, and aircraft ceiling were prepared for the months of October, November, and December. These data indicated that the probability of meteorological conditions favorable for conducting the Sterling Event during the early morning was high.

2.2.2 Operational Analysis Procedures

Teletype data and facsimile charts were the major source of information used in the preparation of the briefing forecasts. Radar reports concerning the precipitation field over Mississippi were provided by telephone as needed by the Radar Observations Section, Weather Bureau Office, New Orleans, Louisiana. These data were plotted and analyzed whenever precipitation activity posed a threat to operations at the Sterling site. Regional streamline analyses of wind data at the two, five, and ten thousand-foot levels MSL, supplemented by analyses of the surface weather pattern as required, were performed locally to provide additional weather information.

On the day of the event, the wind data obtained from local upper-air observation sites and instrument positions were analyzed at each reporting

time to define the existing wind field, determine the trajectory of radioactive materials should leakage occur, delineate the area which would be affected by such a release, and estimate the arrival time of the radioactivity at downwind locations. Temperature profiles were analyzed to determine the thermal stability of the atmosphere and its effect on potential effluent cloud height.

2.3 WEATHER AND RADIATION BRIEFINGS

Formal weather and radiation briefings were presented to the Project Manager and his Advisory Panel at 1500 CST, December 2, and 0400 CST, December 3.

Each formal briefing presentation consisted of the following graphic displays:

1. The latest surface analysis when required to clarify the forecast.
2. The latest 5000-foot MSL streamline analysis.
3. A streamline prognosis for H-hour at two or five thousand feet MSL, the altitude selected depending upon the predicted vertical extent of the potential gaseous cloud.
4. Forecast air trajectories in six-hour increments to H+24 hours at the two and five thousand-foot MSL levels.
5. Forecast clouds, weather, and low-level winds during the period from H-hour to H+12 hours.
6. Predicted vertical profiles of wind and temperature at H-hour.

7. The predicted total external gamma dose due to cloud passage as a function of distance downwind from Ground Zero which would result from the short-period leakage of radioactive gases.
8. The orientation and extent of the area which would be affected by an accidental release of radioactivity, as determined from the predicted shot-time winds.

CHAPTER III

RESULTS

3.1 WEATHER CHRONOLOGY

On December 2, the Sterling site was located on the western periphery of a ridge of high pressure which extended eastward into the Atlantic. This system produced partly cloudy skies and light southerly winds over the southern half of Mississippi. A weak cold front, orientated northeast-southwest, was positioned over extreme northern Mississippi and was moving southeastward. Behind this frontal system, which extended from New England into central Texas, a huge high pressure area, or anticyclone, blanketed the north-central states. This anticyclone was expected to continue moving eastward, pushing the cold front well south of the Sterling site by 0600 CST, December 3. This pattern would produce extensive cloudiness, a likelihood of light rain showers, and southeasterly surface winds over the Sterling site. Winds aloft were expected to remain essentially westerly.

A readiness briefing was held at 1500 CST, December 2, and the weather forecast, valid from 0600 CST to 1800 CST, December 3, presented is summarized as follows:

1. The predicted vertical temperature profile indicates that the mixing layer will extend to about 500 feet above the surface initially and deepen, by mid-day, to about 5000 feet above the surface.
2. The winds at scheduled shot-time, 0600 CST, will veer from 140 degrees at 5 kts. at the surface to 230 degrees at 15 kts. at

5000 feet MSL. As the day progresses, surface winds will become more southerly and upper winds more westerly. Wind speeds at all levels will increase.

3. Scattered to broken stratocumulus and altocumulus clouds and possible scattered light rain showers are anticipated.
4. The air trajectory at 2000 feet MSL is expected to be toward the north, and at 5000 feet MSL, toward the east.

The briefing charts used in the presentation are shown in Figure 3.1.1.

A follow-on weather briefing was held at 0400 CST, December 3, by which time it was apparent that the surface high pressure area was not moving eastward as rapidly as previously anticipated. In addition, the cold front, which passed over the Sterling site near midnight, had not moved as far to the south as had been forecast. Rain and fog were occurring in many areas to the rear of the front. These circumstances required that the following revisions be made to the previous weather forecast:

1. Vertical mixing of any effluent cloud would be confined to the first thousand feet above the surface.
2. The forecast winds at scheduled shot-time will back from 020 degrees at 5 kts. at the surface to 330 degrees at 5 kts. at 1000 feet MSL. Above this point, winds will change abruptly to westerly at speeds of from 15 to 20 kts. The winds in the first thousand feet above the surface will become more easterly during the day but little change in speed is anticipated. The winds above this level will become more southwesterly with time

and speeds will increase slightly.

3. The air trajectory at 1000 feet MSL will be directed toward the south initially, shifting sharply westward after H+12 hours. The trajectory at 2000 feet MSL will be directed toward the east.

4. Broken to overcast stratocumulus, stratus, and nimbostratus clouds are expected over the area. The occurrence of occasional rain and fog at the Sterling site is also anticipated.

The charts used in the 0400 CST briefing presentation are shown in Figure 3.1.2.

Meteorological conditions were acceptable for conducting the Sterling Event on the morning of December 3 and, at 0615 CST, the device was detonated. At shot-time, winds were east-northeast at nine knots at the surface, backing with height to northwest at nine knots at 1000 feet MSL. Lapse, or neutral, stability conditions existed from the surface to about 500 feet; with an extremely stable layer, almost 1500 feet thick, above that point.

The shot-time vertical temperature profile; surface weather map at 0600 CST, December 3; and surface and 2000-foot MSL streamline patterns at 0600 CST, December 3, are presented in Figures 3.1.3, 3.1.4, 3.1.5, and 3.1.6, respectively.

A complete tabulation of meteorological observations for December 3 is available on request from the ARL-LV, Las Vegas, Nevada. The tabulation has been omitted from this report since the release of radioactivity into the atmosphere as a result of the detonation was insufficient to constitute any hazard whatsoever to the off-site population.

3.2 WEATHER FORECAST VERIFICATION

One measure of forecasting skill is the comparison of the Briefing Meteorologist's wind forecasts and "persistence forecasts" with the wind profile actually observed at shot-time. The persistence forecast is made by assuming that the last wind profile observed prior to preparation of the briefing forecast will persist until shot-time. The above comparison is presented in Table 3.2.1, and error evaluations in both speed and direction for each forecast level are shown.

3.3 RADIATION CHRONOLOGY

Prior to the event, the radioactivity which would be produced by the Sterling detonation was confidently expected to be wholly contained within the Salt Dome. The only conceivable accident was the possible emission of a small amount of radioactivity, primarily in the form of noble gases, through a crack or fissure in either the stemming system or the surrounding earthen encasement.

The maximum credible accident condition provided to the Radiation Prediction Unit for the Sterling Event postulated a total of 200 curies of activity at H+1 minute released into the atmosphere within a period of several minutes after detonation. Using this source term, a decay rate of $t^{-1.2}$, the predicted wind conditions, and the estimated vertical rise of the effluent, a prediction of the total external gamma dose along cloud centerline due to effluent cloud passage was made.

The orientation and estimated crosswind extent of the region over

which the cloud would be advected by the predicted winds was presented to the Project Manager and his Advisory Panel to apprise them of the potential area of concern.

Figure 3.3.1 depicts the predicted total gamma exposure dose levels presented at the final 0400 CST briefing on December 3. The initial meteorological conditions used to prepare these estimates were an effluent rise to 500 feet above the surface, a directional shear in the wind ladder through the cloud layer of 30 degrees, and a mean cloud transport speed of 5 mph. Figure 3.3.2 delineates the area over which the effluent cloud was expected to pass. The initial centerline bearing for any release of activity was predicted to be 185 degrees from GZ.

3.4 RADIATION VERIFICATION

On-site radiation data were provided by Reynolds Electrical and Engineering Company and the Lawrence Radiation Laboratory. Off-site surface radiation data were provided by the U. S. Public Health Service. These data were supplemented by aerial survey measurements conducted by the USPHS and EG&G.

The radiation measurements made by these organizations at and for a period of several hours following the detonation of the Sterling device indicated that activity levels remained at normal background. During midmorning, however, the presence of a small amount of radioactive gas was detected in the timing and firing cable. To prevent this activity from seeping along the cable to the Timing and Firing Trailer complex, the cable was severed at a point approximately 1900 feet from GZ and the

end sealed. During the sealing process, a small amount of gaseous radioactivity, mostly noble gases, was released into the atmosphere after being bubbled through the liquid sealing compound. Radiation levels produced by this release were negligible. No positive contacts were reported by either ground or aerial monitors surrounding the release point. All available evidence verifies that the release of activity was extremely small and did not, in any way, constitute a hazard to the off-site population.

CHAPTER IV

POST-SHOT ACTIVITIES

At the direction of the Project Manager, the WRPU maintained a post-shot round-the-clock observing and forecasting capability at the Sterling site in the event that a radiation emergency should arise and cloud tracking activities be initiated. This support was continued through December 4, after which time it was determined that the accidental release of radioactivity into the atmosphere was no longer a threat. On-site meteorological support was then terminated and all ARL-LV personnel returned to Las Vegas.

Event Name: Project STERLING
Sterling Event

Event Date: 12/3/66
Event Time: 0615 CST

Briefing Date: 12/3/66
Briefing Time: 0400 CST
Valid Time : 0615 CST

Briefing Date: 12/2/66
Briefing Time: 1500 CST
Valid Time : 3/0600 CST

Height (Feet) MSL	Observed Wind Dir Spd	Predicted Wind Dir Spd	0600 Z Persistence Wind Dir Spd	Error Predicted Wind Dir Spd	Error Persistence Wind Dir Spd	Predicted Wind Dir Spd	1200 Z Persistence Wind Dir Spd	Error Predicted Wind Dir Spd	Error Persistence Wind Dir Spd
7000	310 12	280 15	--- ---	030 03	--- ---	270 20	260 21	040 08	050 09
6000	310 13	270 20	--- ---	040 07	--- ---	250 15	280 20	060 02	030 07
5000	290 15	260 20	--- ---	030 05	--- ---	230 15	290 19	060 00	000 04
4000	280 18	260 20	--- ---	020 02	--- ---	190 10	290 17	090 08	010 01
3000	260 18	250 20	230 23	010 02	030 05	170 10	260 17	090 08	000 01
2000	290 13	250 15	230 18	040 02	060 05	160 05	240 17	130 08	050 04
1000	310 09	330 05	270 09	020 04	040 00	150 05	220 05	160 04	090 04
Sfc.	065 09	020 05	300 04	045 04	125 05	140 05	Calm	075 04	--- ---

NOTE: Directions are recorded in whole degrees and speeds in whole knots.

NOTE: Persistence wind forecast is the latest actual winds aloft report available to the forecaster at the time the forecast was prepared.

TABLE 3.2.1 Wind Forecast Verification

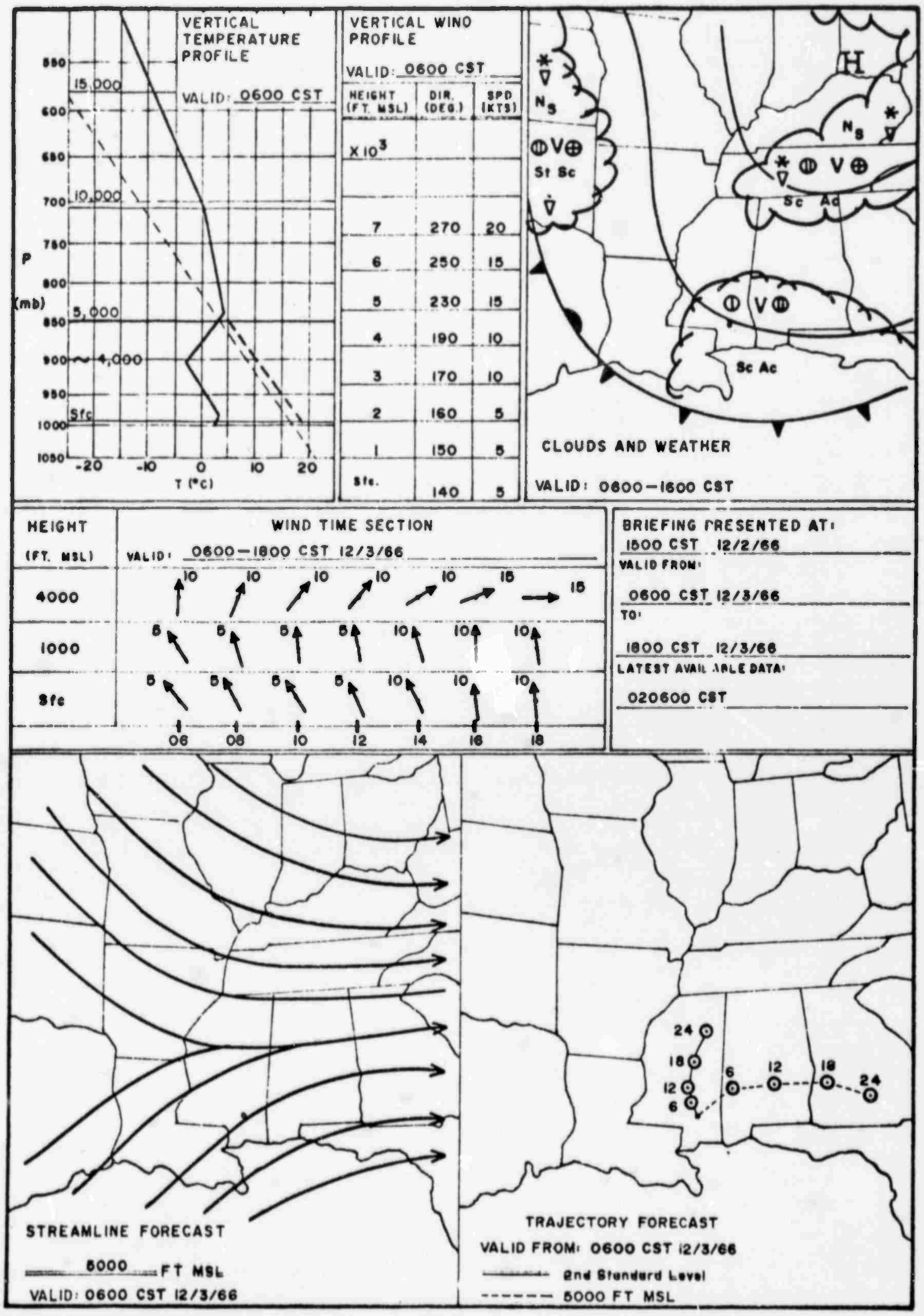

Fig. 3.1.1 Weather Briefing Chart — 1500 CST, December 2, 1966

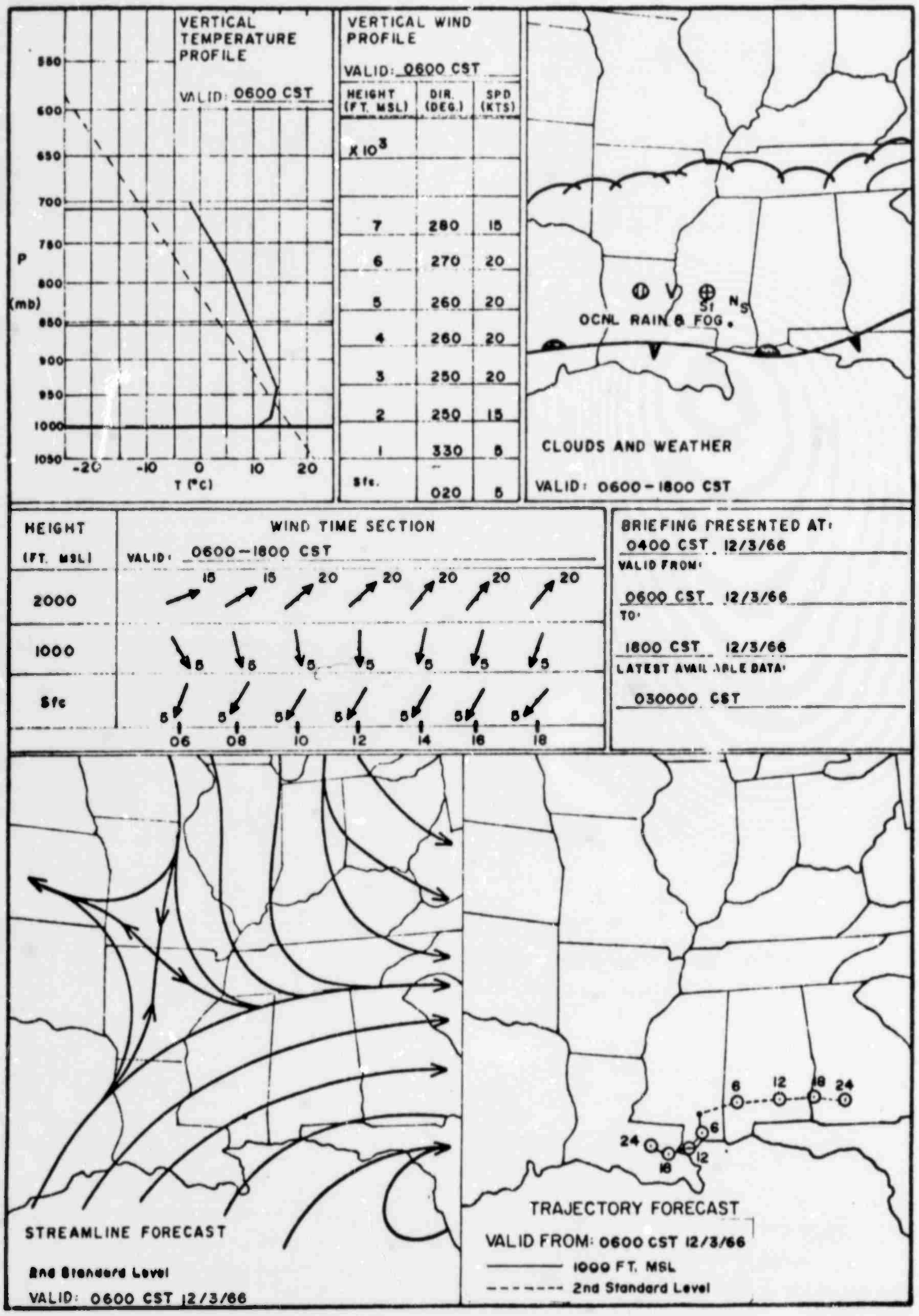

Fig. 3.1.2 Weather Briefing Chart — 0400 CST, December 3, 1966

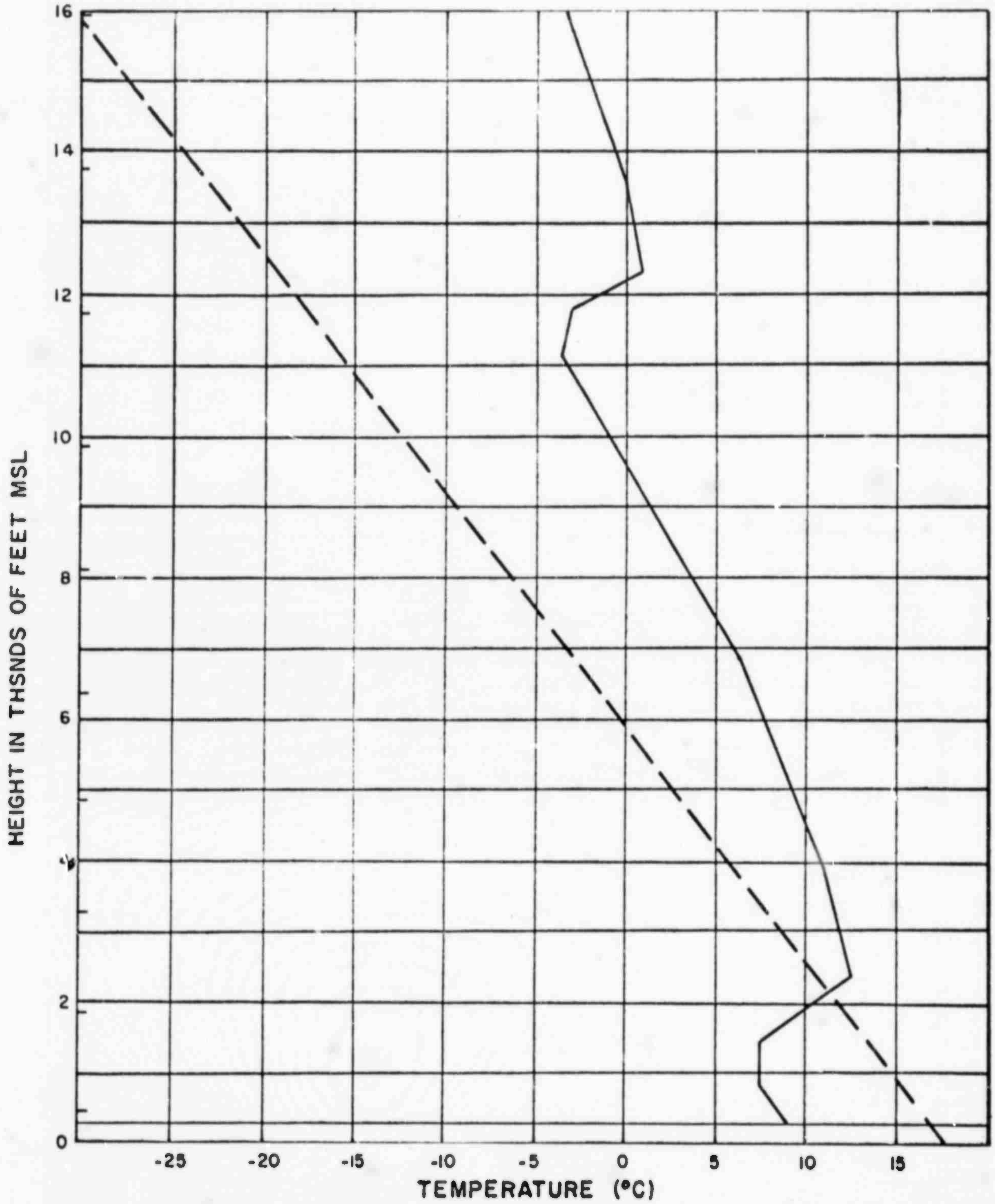

Fig. 3.1.3 Vertical Temperature Profile — 0515 CST, December 3, 1966

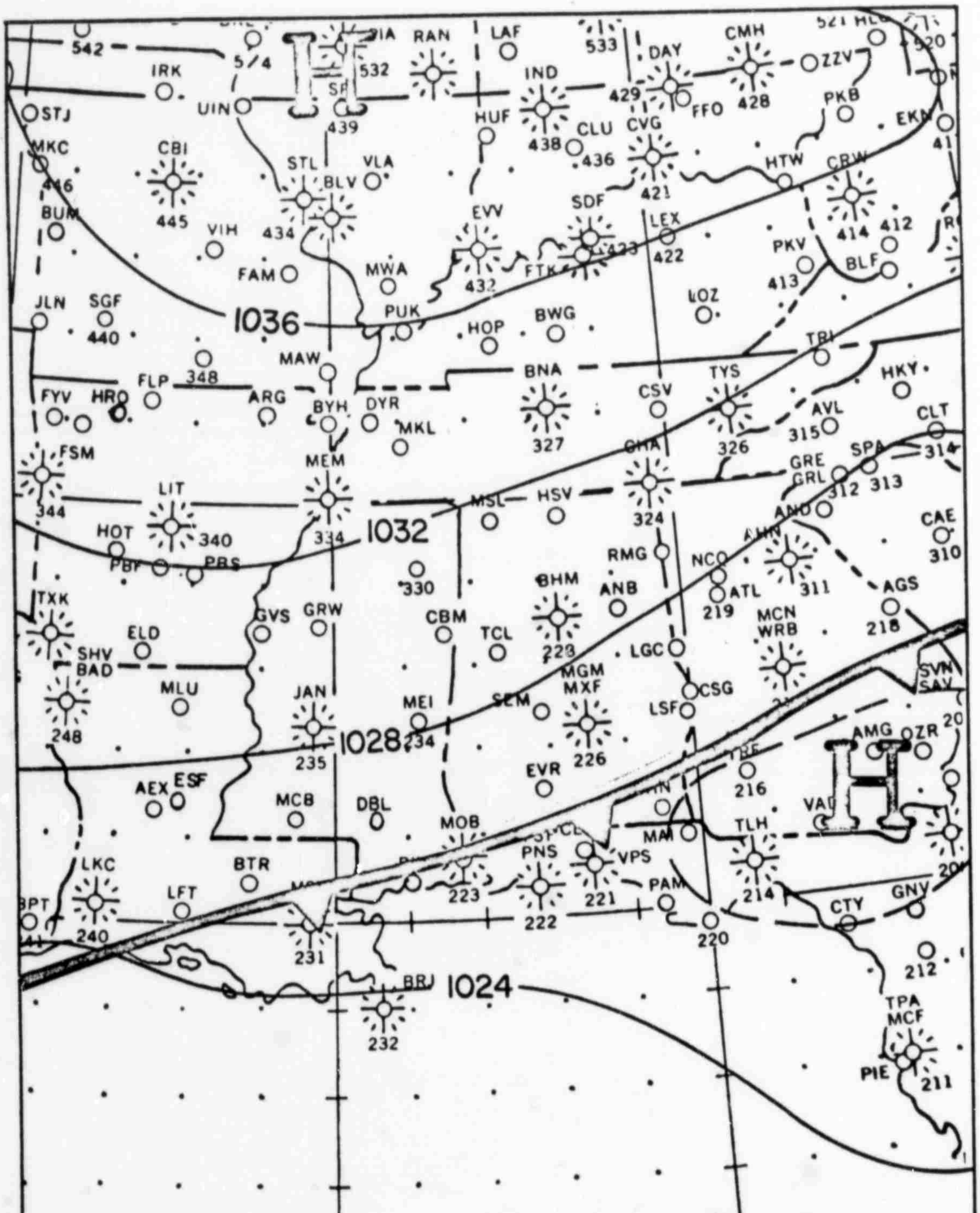

Fig. 3.1.4 Surface Analysis — 0600 CST, December 3, 1966

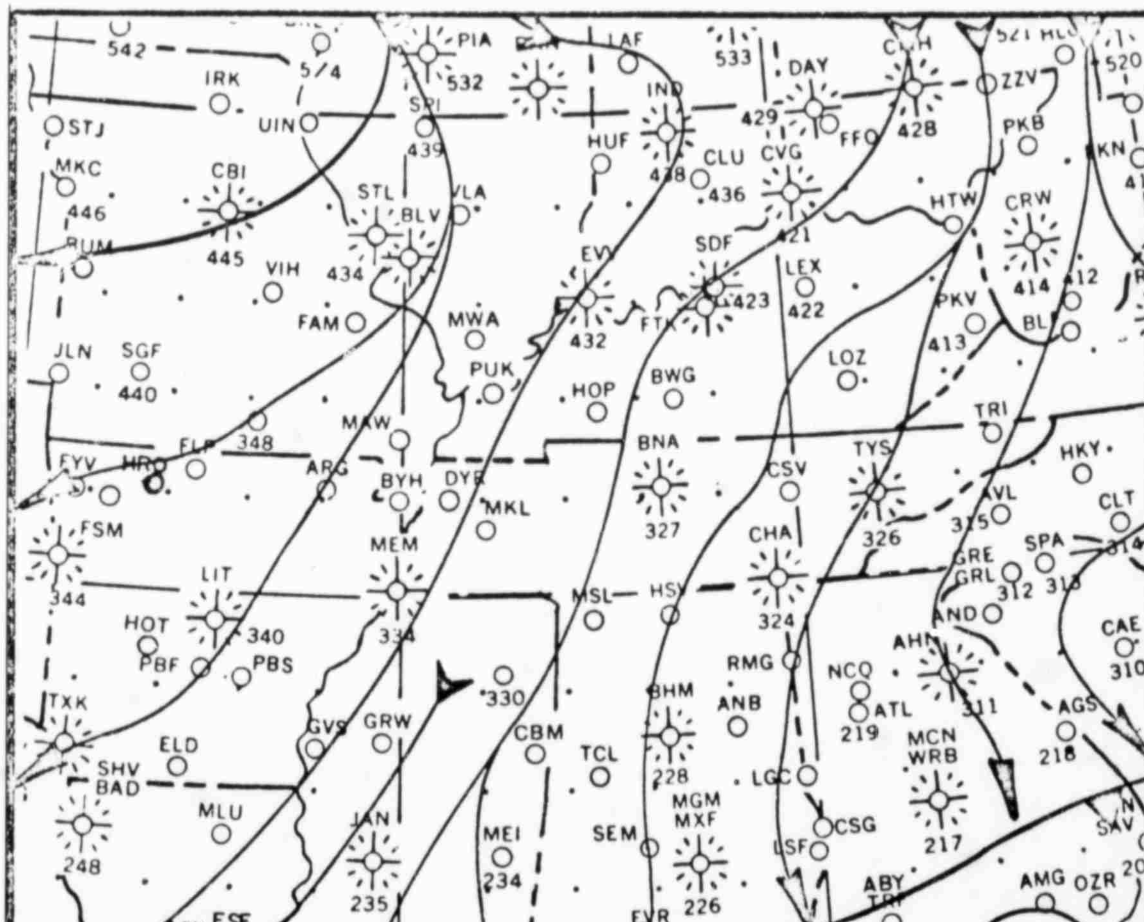

Fig. 3.1.5 Surface Streamline Analysis — 0600 CST, December 3, 1966.

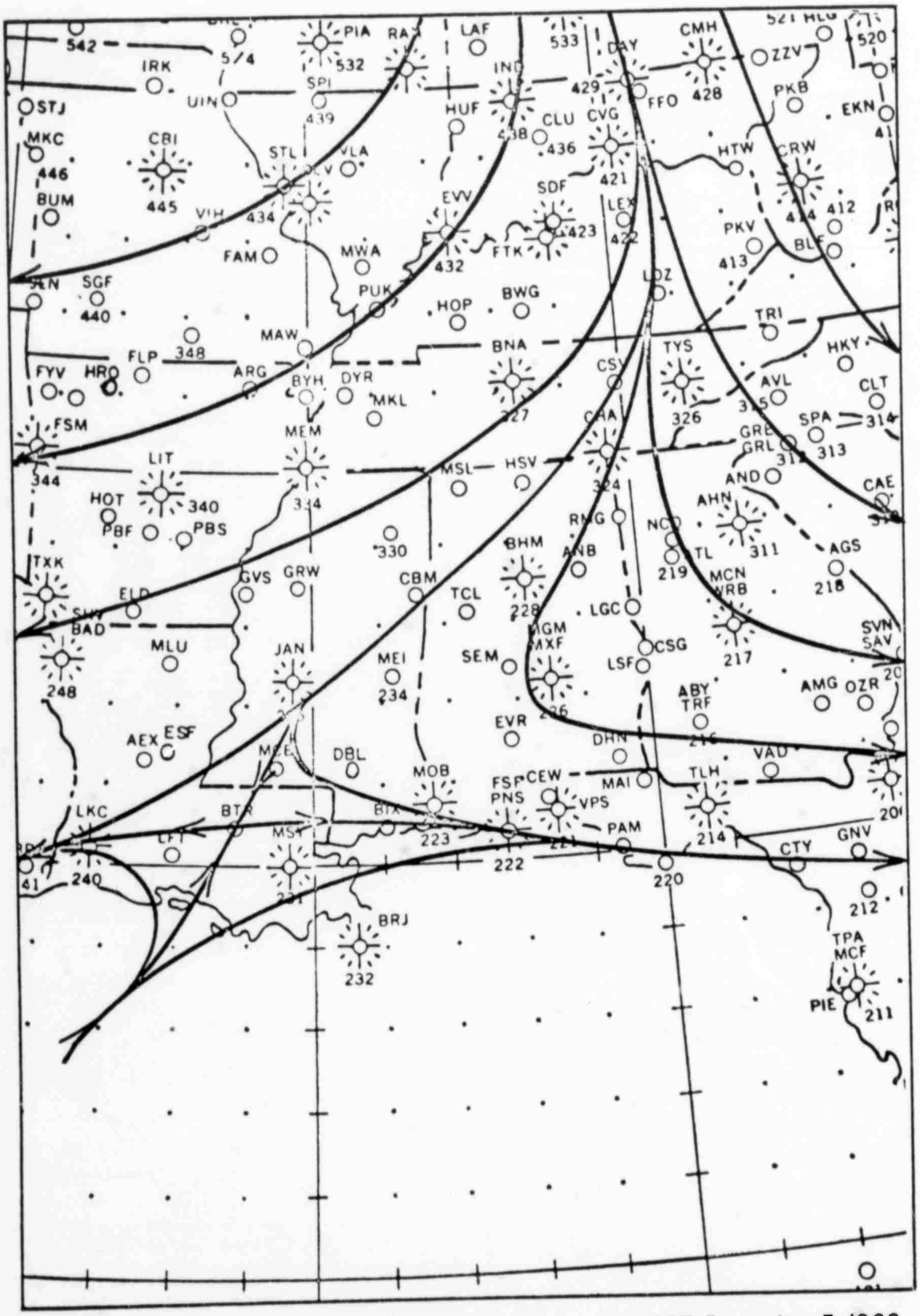

Fig. 3.1.6 2,000-Foot MSL Streamline Analysis—0600 CST, December 3, 1966

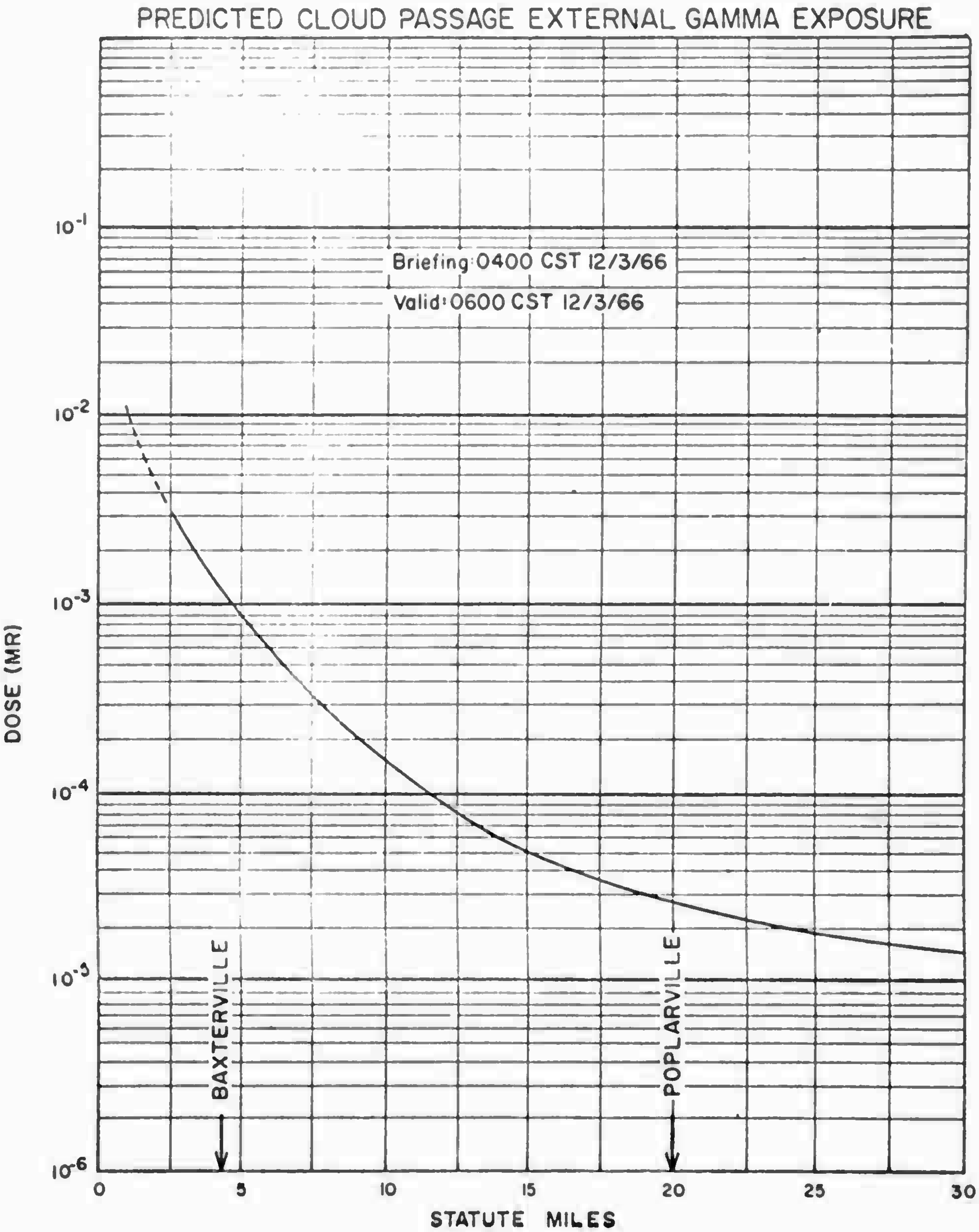

Fig. 3.3.1 Predicted Total Gamma Exposure Dose Due To Cloud Passage

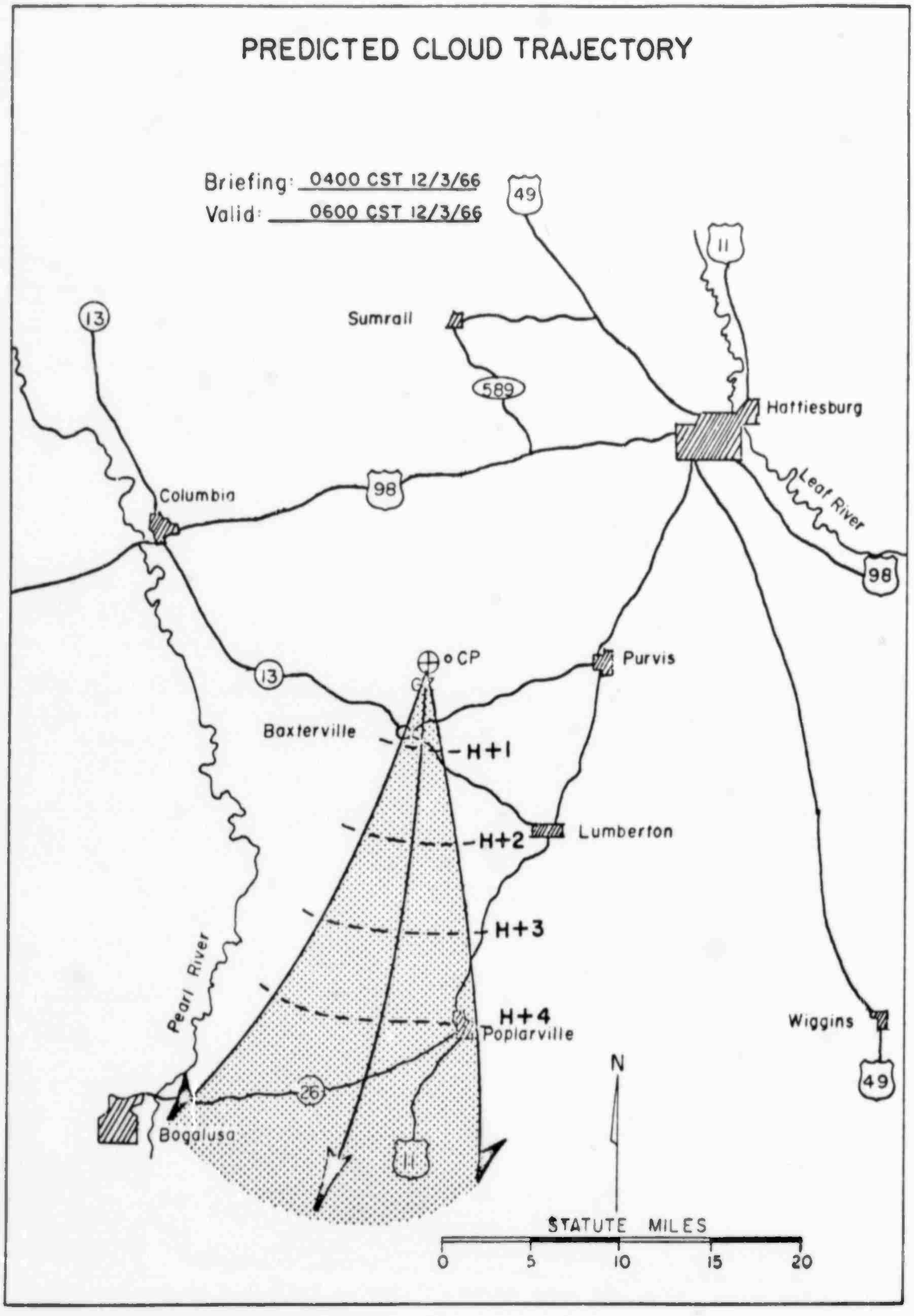

Fig. 3.3.2 Predicted Cloud Path

PROJECT STERLING REPORTS

SAFETY REPORTS

Agency	Report No.	Title
ERC	VUF-1035	Analyses of Ground Motion and Containment
USPHS	VUF-1036	Off-Site Surveillance
ESSA/ARFRO	VUF-1037	Weather and Surface Radiation Prediction Activities
REECo	VUF-1038	On-Site Health and Safety
FAA	VUF-1039	Federal Aviation Agency Airspace Advisory
H-NSC	VUF-1040	Hydrologic Safety Evaluation
USBM	VUF-1041	Pre- and Post-Shot Safety Inspections of Oil and Gas Facilities
USGS	VUF-1042	Well Aquifer Response to the Sterling Event, Tatum Dome
USGS	VUF-1043	Chemical and Radio-Chemical Quality of Water Following the Sterling Event
JAB	VUF-1044	Structural Response

TECHNICAL REPORTS

LRL, SC	VUF-3025	Subsurface Phenomenology Measurements Near a Decoupled Nuclear Event
USC&GS USGS GEO TECH LRL	VUF-3026	Decoupling of Seismic Waves By a Shot-Generated Cavity
TI	VIF-3027	Radioactive Gas Analysis
II	VUF-3028	Detection of Radionuclides

List of Abbreviations for Technical Agencies
Participating in Project Sterling

ERC	Environmental Research Corporation Alexandria, Virginia
ESSA/ARFRO	Environmental Science Services Administration Air Resources Field Research Office Las Vegas, Nevada
FAA	Federal Aviation Agency Los Angeles, California
GEO TECH	Geotechnical Corporation Garland, Texas
H-NSC	Hazelton-Nuclear Science Corporation Palo Alto, California
II	Isotopes, Inc. Westwood, New Jersey
JAB	John A. Blume San Francisco, California
LRL	Lawrence Radiation Laboratory Livermore, California
REECo	Reynolds Electrical & Engineering Co., Inc. Las Vegas, Nevada
SC	Sandia Corporation Albuquerque, N. M.
TI	Texas Instruments, Inc. Dallas, Texas
USBM	U. S. Bureau of Mines
USC&GS	U. S. Coast & Geodetic Survey Las Vegas, Nevada
USGS	U. S. Geologic Survey Denver, Colorado
USPHS	U. S. Public Health Service Las Vegas, Nevada